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Exploring the National Role and Position of International Technology Diffusion: A Technological Embeddedness Perspective

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***Abstract*--The international diffusion of technology is one of the most important topics in economics and technology policy research. Countries participating in a global network demonstrate interdependence and mutually influence one another. Characteristics in network structure indicate the complexity of the overall network configuration. This study uses social network analysis to investigate the structural configuration of international technology diffusion. This research utilizes a collective behavioral analysis of social embeddedness to reveal a country's role and position as factors in international technology diffusion. Role and position analysis categorize network actors based on behavioral performance in regards to technology mobility source, transmitter, and receiver processes. This analysis provides insights into the global technological embeddedness of countries, and also proposes a technological development perspective for global network embeddedness. The study results not only identify the competitive position of countries in the global network, but can also provide policy makers with a new perspective in exogenous technological growth.**

I. INTRODUCTION

Globalization, global outsourcing, global design and global supply chains carry out international science and technology diffusion. Diffusion can refer to the dissemination of knowledge, technology transfer or deployment [1], and is a process that involves spreading certain innovation information via participants in a social system using particular channels [2]. Diffusion is an exceptional form of communication, involving participants in providing and sharing information. Meanwhile, the international diffusion of technological knowledge is an important issue that has been frequently studied. A review of the literature reveals that most current studies focus on the impact of international technology diffusion on domestic productivity gains from the perspective of individual countries. However, little attention has been given to a multilateral perspective of the network structure of technology diffusion within the larger international economy. A multilateral perspective would allow us to accurately assess the competitive positions of countries within the international diffusion network and to view them in context with other nations.

Despite numerous studies which examine technology dissemination and global interactivity and propose contingency perspectives [e.g. 3, 4-7], it is still questionable whether these structural perspectives can perfectly interpret current complex global circumstances. More specifically, it remains uncertain which characteristics of a network structure exist within international technology diffusion. What features exist? What is the dissemination proximity that exists in a given system?

Although current literature provides numerous important insights, many of the questions raised above remain unanswered. Questions related to multilateral interactivity are best understood as social network issue. Social network analysis explores the relationship between actors [8]. Sociologists study social networks in which the nodes can be people, groups, roles or other sociological categories. The ties between these nodes are classified as social relations. Network theorists treat network structures within the "embeddedness" perspective associated with Granovetter [9]. Moreover, Podolny, Stuart et al., [10] argue that an organization's niche is its position in a technology space. In other words, an organization's competitiveness emerges from a position of technological contact with the inventions of other organizations. Therefore, this work examines the global network of technology to explore features of diffusion and embeddedness.

II. LITERATURE REVIEW

A. International technology diffusion and technology embeddedness

International technology diffusion can refer to the dissemination of knowledge, technology transfer or deployment [1]. Technology diffusion is influenced by innovations and technical updates over time. Countries acquire innovation technology in two key ways; by enforcing domestic technology development and innovation capacity, and obtaining advanced technologies via international technology diffusion [11-13]. Griliches [14] divides international technology diffusion into rent spillover and pure knowledge spillover. Rent spillover refers to the price of new products for which innovation technology knowledge exists, but cannot fully reflect the high quality of knowledge innovation in the process of commercialization. A country purchasing intermediate products at a certain price without mirroring their actual value can enjoy the benefits of R&D conducted by other countries; that is, the purchasing country employs passive technology spillover or embodied technology diffusion [15] to supply their innovation capacity. This work investigates imports of machinery and equipment for diffusing embodied technology information. Countries that exchange goods through international trade generate rent spillover.

Pure knowledge spillover, as well as the inherent knowledge simulated and adopted by others, emerges primarily by externalities in the form of flows of research and development personnel, knowledge mobility. Dissemination emerges via cooperation, international technology learning, or the direct purchase of foreign technology knowledge. Advantages of innovation activity are reflected in the process of commercialization [15]; that is to say, an effective method of measuring national competitiveness in a disembodied form is through patent citation frequency. Pure knowledge spillover results from disembodied knowledge flows, including licensing, patent citations, or outsourcing agreements. Griliches [16] suggests that patent citations can be measured as a disembodied form of diffusion. Hence, this study adopts patent citations as a means of disembodied technology diffusion. Countries citing their patents in relation to others generate pure knowledge spillover.

However, international technology mobility involves several different channels [17, 18]. Whether these alternate channels exist as differential features is uncertain. Therefore, exactly which international technology structures exist and differences in their diffusion channels must be identified.

Despite various contingency perspectives in international cooperation proposed by previous studies, the issue of international social proximity as a structural configuration remains uncertain. Questions related to multilateral interactivity are best understood as a network issue, and few explicit network analyses of these questions exist. Applications of social network analysis are widely spread, especially in the field of sociology in areas such as social support or social capital. In recent years, the methods of social network analysis have been applied to science and technology studies [19-23]. Social network analysis explores the relationship (ties) between actors (nodes) [8]. Sociologists study social networks in which the nodes can be people, groups, roles or other sociological categories, and the ties are social relations. Furthermore, collective behavior can be reflected as a network feature between several groups. Sociologists term this distinctive feature as a “clique”. However, clique research in terms of network structures have been predominately in terms of a “macro” perspective [24].

B. Network Embeddedness analysis

Scott [24] simplifies the concept of a clique as a “maximal complete sub graph” by defining it as the biggest collection of people who all have connections with everyone else in a group. Social network scholars [25] make generalizations about social behavior and social structures. They theorize about somewhat more abstract ways of making sense of the patterns of relations among social actors as the analysis of “equivalence classes.” As an empirical task, this work needs to be able to group together actors who are the most similar, to describe what makes them similar and to further describe what makes them different, as a category, from members of other categories. The network concept used to group subsets in terms of individuals sharing the same relations is called equivalence, and the network technique used to identify such subsets is called “blockmodeling” [e.g. 26, 27, 28]. In contrast, sociological thinking routinely uses abstract categories. General attributes, for example, “Men” and “Women” are really labels for categories of persons who are more similar within a category than between categories, at least for the purposes of understanding and predicting aspects of their social behavior. When categories like these are used as parts of sociological theories, they are being used to describe the “social roles” or “social positions” typical of members of the category.

Hanneman and Riddle’ research [29] indicates embeddedness structural analysis is not particularly concerned with systems of categories (i.e., variables) that are based on descriptions of similarity of individual attributes. Structural analysts seek to define categories and variables in terms of similarities of the patterns of relations among actors, rather than the attributes of actors. That is, the definition of a category, or a social role or position, depends upon its relationship to another category. Social roles and positions, structural analysts argue, are inherently “relational.” Each one of these categories (i.e., supplier, custom) can only be defined by regularities in the patterns of relationships with members of other categories. With is structural analyst perspective, the building blocks of social structure are social roles or social positions. These social roles or positions are defined by regularities in the patterns of relations among actors, not attributes of the actors themselves. We identify and study social roles and positions by studying relations among actors, not by studying attributes of individual actors.

Related research into role structure had similar position-role hypotheses, such as in a journal network by Doreian [30, 31], and Doreian and Fararo [32], in diffusion of technology by Harkola and Greve [19], and Graeme and Tabarak [33]. Doreian and Fararo [32]. Each argued that the structure of the ties in the citation network can be used to establish a set of positions (statuses). Furthermore, the actors of the network represent patents, inventions or scientific papers, and the ties represent patent citations as technological commonalities linking patents to prior art [34]. Sternitzke, Bartkowski et al. [35] argued that network analysis allows researchers to identify the following: first, to identify important players in technology fields or corporations; second, to identify connections among players, which can be used for competitor analysis or for identifying partners for joint development projects; third, to identify methodologies which allows the identification of key patents; and fourth, to evaluate rivalries between players in the technology field. Therefore, role and position analysis enables researchers to understand and identify clique categories within a given global technology structure.

C. Network role and position analysis

Social roles and their functions within a social system have been analyzed by numerous sociologists. Parsons [36] proposed a “structure of social action”, implying that a social system consists of several subsystems, and that those subsystems have inherited a function specific to the social system. Therefore, a social system may be better understood by investigating the relationships between its subsystems. Burt [21] identified the role of an actor as a pattern of relationships with others. In the other words, a set of positions consists of a group of network actors play their various roles. Thus, a set of positions can represent a kind of role play.

In terms of a network position perspective, Burt [21] proposed the function of different roles by looking at the pattern of relationships among different positions. After investigating academic paper citations, Burt identified “Primary”, “Sycophant”, “Broker”, and “Isolate” roles according to the placement of positions within a network and the tendency for actors in structurally equivalent positions to initiate interactions only with each other. These positions identify an actor’s social standing within a group and act as a proxy for their interactive behavior and social competencies.

The primary position receives ties both from members of other positions and from its own members. Primary positions represent the prototype of socially prestigious actors as they receive social approval from other positions. Brokers both receive and send ties to members of other positions. More specifically, this position receives and reciprocates at the same time. Brokers are also often referred to as “ordinaries”, as they represent the most common position in groups. A sycophant has more ties to members of other positions than to one another, and do not receive many ties. Sycophants reflect the idea of actors trying to tag along while their attempts at social connections are not reciprocated by others. Isolate positions neither give many ties nor direct many ties to other positions. This position deliberately does not promote ties, nor does it receive social approval. Burt’s role typology simultaneously considers inter-block relationship and intra-block relationships. For these reasons, this study adapts Burt’s diffusion pattern analysis.

TABLE 2-1: BURT’S FOUR-POSITION TYPOLOGY

		received by position (inter-block)	
		High	Low
within position (intra-block)	High	***Primary***	***Isolate***
	Low	***Brokers***	***Sycophants***

Source: Burt (1976)

Galaskiewicz and Krohn [37], however, proposed a separate model of role identification based on resource dependency theory. From this perspective, the function of a particular role can be inferred by examining that position’s resource dependency patterns within a given network. Galaskiewicz and Krohn investigated global dependency roles or positions via linkage directions and their extensions. They proposed four roles: “Generators”, “Consumers”, “Transmitters” and “Isolates”.

TABLE 2-2: GALASKIEWICZ AND KROHN’S FOUR-POSITION TYPOLOGY

		Outward linkage	
		High	Low
Inward linkage	High	***Transmitters***	***Consumers***
	Low	***Generator***	***Isolates***

Source: Galaskiewicz and Krohn (1984)

Generators are actors in which others in the network are dependent upon for a given resource. Actors in these positions transfer control of a particular resource to other positions in the network without themselves being dependent upon the network for that resource. Consumers are highly dependent upon other actors in the network for a given resource. Actors in these positions receive the resource from others, but they do not provide other positions with this resource. Transmitters receive a resource from positions in the network and also provide that resource to other positions. Isolates are not dependent upon other positions in the network for a resource, nor are others dependent upon them. Galaskiewicz and Krohn [37] proposed role character focus upon inter-block relationship rather than intra-group activity. This role characteristic can interpret interactions between diffusive blocks.

III. DATA AND METHODOLOGY

A. Data

This investigation employs a sample of 42 countries from 1997 to 2008. The 42 countries were derived from the nations topping the Global Competitiveness Index of the World Competitiveness Databank [38]. The international technology diffusion dataset contains three categories: bilateral trade in exports, bilateral trade in imports, and aggregate R&D Expenditure. In considering the completeness of data collection, this investigation selected these 42 countries as the sample in part because materials for some countries were absent and these 42 countries provided the most complete data. Appendix A provides a complete list of the countries studied in this work.

Numerous studies [e.g. 3, 14, 39, 40] indicate total national R&D expenditure is positively and significantly related to international technology diffusion. Thus, Xu and Wang [41], as well as Shih and Chang [42] proposed that international technology diffusion be measured based on national R&D expenditure multiplied by a weighted coefficient. This study also considers total national R&D

expenditure when measuring the degree of international technology diffusion, and a detailed description is shown below. The World Competitiveness databank from the International Institute for Management Development (IMD) also provides the total R&D expenditure of each country, and this investigation refers to this data to formulate ITD matrixes. Numerous studies [e.g. 43, 44, 45] utilize this databank to investigate economic performance in regional cooperation, national technological capacity, and political rights.

In terms of embodied form technology, trade flow data were mainly obtained from the Global Trade Information Services databank (GTI). Coe *et al.* [46] found that it is better to measure trade-related spillover using trade in capital goods rather than total trade. Furthermore, previous studies [e.g. 16, 47-49] indicate that international trade of machinery and transport equipment (SITC-7) imply technological manufacture better than other items. The SITC-7 includes nuclear reactors, boilers, machinery, mechanical appliances, vehicles, railways, tramway rolling stock, electrical machinery and equipment and parts thereof; sound recorders and reproducers, television recorders and reproducers, and parts and/or accessories. Subsequently, the SITC-7 has been applied in embodied technology trade flow research by numerous scholars [e.g. 46, 50-52]. However, for bilateral trade data, a dataset can divided into an import data sheet and an export data sheet. Several studies [e.g. 53, 54] argue that import data are more accurate than those on export data, and this study adopts an import dataset separated from technology .

B. Methodology

1. Measurement of international technology diffusion

This work employs network matrixes to examine spillovers in international technology diffusion. Since total national R&D expenditure is positively and significantly related to international technology diffusion [3, 14, 39, 40], Xu and Wang [41] and Shih and Chang [42] propose that international technology diffusion can be measured based on national R&D expenditure multiplied by a weighted coefficient. This study considers total national R&D expenditure when measuring the degree of international technology diffusion.

Regarding the measurement of international technology diffusion, this study adopts the most common method for measuring spillovers, R&D expenditures of other countries multiplied by different share weights, as defined by Griliches [14]. Equation (1) shows the formula.

$$ITD_{ij} = r_{ij} \times RD_i \text{ ……………………………………………(1)}$$

Here, ITD_{ij} represents the degree of technological knowledge diffusion from country i to country j, RD_i is the R&D expenditure of country i, and r_{ij} represents the fraction of knowledge spillover from country i to country j. This study defines the weighting of embodied form diffusion as $r_{E,ij,t}$ [42].

$$r_{E,ij,t} = \frac{M_{ij,t}}{\sum_{i=1}^{l}\sum_{j=1}^{l} M_{ij,t}} \qquad i \neq j, \quad i,j,l = 1,2\ldots,42 \text{ ……….(2)}$$

$M_{ij,t}$ represents country j importing capital goods from country i during year t; l stands for numbers of countries, from 1 to 42. Trade flows in this study are measured as the quantity of machinery and equipment imports in one country multiplied by the total R&D expenditure in another country; imports and exports to and from 42 countries forms a 42 x 42 matrix. This study assumes that if a certain country imports more capital goods from other countries, the net importer nation will benefit through embodied technology diffusion.

2. Block model analysis and countries classified

After the IDT matrix has been formatted, network data can be analyzed using a blockmodel. In network analysis terms, this technique distinguishes subsets of a network based on individuals sharing the same relations. In Figure 1, it is easy to see the class of five nodes at the lowest level of the network hierarchy E, F, G, H, and I. These actors are regularly equivalent to one another because they have no ties with any actor in the highest level (A), and each has a tie with an actor in the second level (B, C, or D). Each of the nodes has an identical pattern of connections with other node levels, even though the actual number of ties with nodes in other regular equivalent classes might vary. For the same reason, nodes B, C, and D form a regular equivalent class, while A, in structural and isomorphic equivalences, is in a class by itself. In a social context, one can think of the family structure as an example of regular equivalence. Assume each of two families has three generations: grandparents, parents, and children. The grandparents of the two families are regularly equivalent even though they might have different numbers of children (parents in the family tree), and their children might also have different numbers of children.

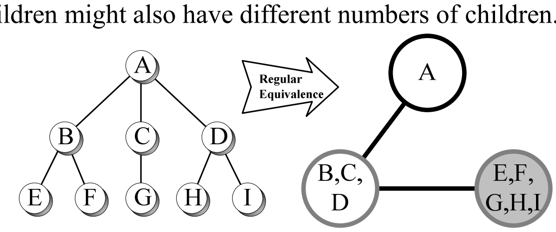

Figure 3-1: Blockmodel based on regular equivalence

Regular equivalence is a better concept to capture the social roles that act as the basic building blocks of social institutions. Once the positions have been identified, the network of roles between the positions can be explored. It is important to see the concept of structural equivalence as applying to social positions, and not simply to roles or proto-roles [24]. Trade data can be configured as a binary. Therefore, the pattern of treading/citation of N countries are represented by a country-to-country matrix consisting of N rows and columns. The position of any country is embedded in the treading/citation network given by the treading/citations sent to and received from the other countries in the network. A position within a social system is defined by an actor's pattern of social relations [27]. Therefore, the position of a country is given by the vector obtained by joining the row and column corresponding to that country. Two countries having exactly the same pattern of export/citing and import/cited ties are regarded as structurally equivalent to one another. Actors who share a similar pattern of social relations are deemed equivalent [55]. This study assumes that two countries are technologically similar to the degree that they are structurally equivalent in the international technology diffusion network [56]. Therefore, the method is derived from regular equivalence and is associated with the REGE algorithm [57] adopted by Smith and White [53]. Regular equivalence is the least restrictive of the three most commonly used definitions of equivalence. This study uses the REGE algorithm as the blockmodeling approach for determining blocks in technology diffusion networks. By applying the REGE algorithm to the study of international technology diffusion, it is possible to distinguish blocks of countries in the embodied diffusion networks based on patterns in their network ties, and patterns of aggregate relations among these blocks can be identified. The specific result of country classification is presented in Appendix A.

3. Network density

Density can be categorized into measurement of an actor and a group or graph. This study utilizes group density to analyze network interactivity. In a directed graph, density is represented as Δ, the ratio of number of lines or arcs present to the maximum possible number that could arise [58]. Each line or arc is given a value of 1, and pairs of nodes forming absent lines are given a value of zero. To generalize the notion of density to a value graph or digraph, one can average the values attached to the lines/arcs. Wasserman and Faust [59] indicate that the density of a directed graph is equal to the proportion of arcs present in the graph. This is calculated as the number of arcs, L, divided by the possible number of arcs. Since an arc is an ordered pair of nodes, there are $g(g-1)$ possible arcs. The density for directed graph is expressed in Equation (3).

$$\Delta = \frac{L}{g(g-1)} \quad \text{……………………………………………(3)}$$

The density of a digraph is a fraction that goes from a minimum of zero (no arcs present) to a maximum of 1 (all arcs are present). If the density is equal to 1, then all dyads are mutual.

IV. RESULTS AND DISCUSSION

Social role and position analysis provide a macro perspective for investigation into global activity. In this section, this work investigates the blockmodel representing the entire configuration of blocks expressed in the density matrix. In addition, it is important for sociologists to distinguish subsets in a network in terms of individuals or social positions according to the relations they maintain with others. This defines an individual's social role in a social network.

A. Global Technological Embeddedness: position analysis and role identification

Network density analysis is used to investigate extended blocks of interactivity. Thus, this section focuses on the density matrix shown in Table 4-1 and Table 4-2 to evaluate intra-block and inter-block relationships. Meanwhile, network positions or roles were identified by means of block relations.

In considering international technology diffusion as a social system, several countries consist of a group, and their blocks demonstrate interactive patterns with one other. Therefore, role-playing and position in the technology diffusion network can be examined. Previous studies show that network position may effect actors in terms of opportunity, constraint, and behaviors [60]. Furthermore, Harland [61] indicates that in terms of international trade, different network positions effect treading control power and information contact.

Burt [21], Galaskiewicz and Krohn [37] have proposed a position typology in order to provide empirical results in network analysis. For visualization purposes, the results in Table 4-1 and Table 4-2 are expressed as a reduced graph in Figure 4-1. The reduced graph shows network density; the arrow direction represents sending and receiving relationships between two blocks.

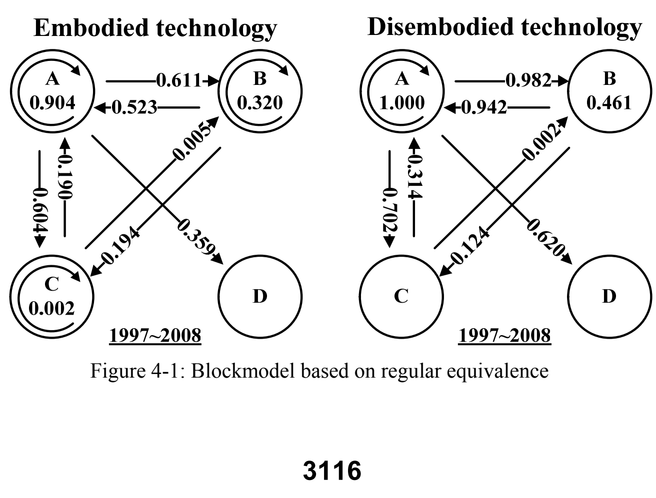

Figure 4-1: Blockmodel based on regular equivalence

TABLE 4-1: BLOCKS DENSITY OF EMBODIED AND DISEMBODIED TECHNOLOGY NETWORKS

Embodied technology network

Periods	A block				B block				C block				D block			
	A	*B*	*C*	*D*	*A*	*B*	*C*	*D*	*A*	*B*	*C*	*D*	*A*	*B*	*C*	*D*
1997-1998	***0.955***	0.610	0.611	0.400	0.557	***0.234***	0.175	0.000	0.194	0.000	***0.000***	0.000	0.000	0.000	0.000	***0.000***
1999-2000	***0.947***	0.678	0.630	0.389	0.556	***0.357***	0.156	0.000	0.250	0.015	***0.014***	0.000	0.000	0.000	0.000	***0.000***
2001-2002	***0.862***	0.559	0.611	0.325	0.446	***0.391***	0.231	0.000	0.211	0.000	***0.000***	0.000	0.000	0.000	0.000	***0.000***
2003-2004	***0.868***	0.595	0.619	0.333	0.495	***0.324***	0.211	0.000	0.155	0.000	***0.000***	0.000	0.000	0.000	0.000	***0.000***
2005-2006	***0.910***	0.615	0.582	0.372	0.529	***0.313***	0.188	0.000	0.176	0.009	***0.000***	0.000	0.000	0.000	0.000	***0.000***
2007-2008	***0.885***	0.611	0.571	0.333	0.553	***0.304***	0.205	0.000	0.154	0.009	***0.000***	0.000	0.000	0.000	0.000	***0.000***
Descriptive statistic																
Mean	***0.904***	0.611	0.604	0.359	0.523	***0.320***	0.194	0.000	0.190	0.005	***0.002***	0.000	0.000	0.000	0.000	***0.000***
Standard deviation	***0.036***	0.035	0.020	0.029	0.040	***0.049***	0.025	0.000	0.034	0.006	***0.005***	0.000	0.000	0.000	0.000	***0.000***
Min.	***0.862***	0.559	0.571	0.325	0.446	***0.234***	0.156	0.000	0.154	0.000	***0.000***	0.000	0.000	0.000	0.000	***0.000***
Max.	***0.955***	0.678	0.630	0.400	0.557	***0.391***	0.231	0.000	0.250	0.015	***0.014***	0.000	0.000	0.000	0.000	***0.000***

Disembodied technology network

Periods	A block				B block				C block				D block			
	A	*B*	*C*	*D*	*A*	*B*	*C*	*D*	*A*	*B*	*C*	*D*	*A*	*B*	*C*	*D*
1997-1998	***1.000***	0.992	0.218	0.889	0.942	***0.524***	0.193	0.000	0.486	0.015	***0.000***	0.000	0.000	0.000	0.000	***0.000***
1999-2000	***1.000***	0.992	0.809	0.513	0.915	***0.329***	0.105	0.000	0.273	0.000	***0.000***	0.000	0.000	0.000	0.000	***0.000***
2001-2002	***1.000***	0.939	0.741	0.400	0.871	***0.364***	0.061	0.000	0.278	0.000	***0.000***	0.000	0.000	0.000	0.000	***0.000***
2003-2004	***1.000***	0.977	0.796	0.603	0.962	***0.480***	0.158	0.000	0.245	0.000	***0.000***	0.000	0.000	0.000	0.000	***0.000***
2005-2006	***1.000***	1.000	0.833	0.633	0.992	***0.511***	0.091	0.000	0.273	0.000	***0.000***	0.000	0.000	0.000	0.000	***0.000***
2007-2008	***1.000***	0.990	0.818	0.680	1.000	***0.557***	0.139	0.000	0.327	0.000	***0.000***	0.000	0.000	0.000	0.000	***0.000***
Descriptive statistic																
Mean	***1.000***	0.982	0.702	0.620	0.947	***0.461***	0.124	0.000	0.314	0.002	***0.000***	0.000	0.000	0.000	0.000	***0.000***
Standard deviation	***0.000***	0.020	0.219	0.151	0.044	***0.085***	0.044	0.000	0.081	0.006	***0.000***	0.000	0.000	0.000	0.000	***0.000***
Min.	***1.000***	0.939	0.218	0.400	0.871	***0.329***	0.061	0.000	0.245	0.000	***0.000***	0.000	0.000	0.000	0.000	***0.000***
Max.	***1.000***	1.000	0.833	0.889	1.000	***0.557***	0.193	0.000	0.486	0.015	***0.000***	0.000	0.000	0.000	0.000	***0.000***

Note: the value numbers express as **bold** and ***italic*** type is "***Reflexive density***"; other is "Inter-block density"

TABLE 4-2: AVERAGE BLOCK DENSITIES

		Embodied				Disembodied			
		A	B	C	D	A	B	C	D
Inter-block density	***Inward***	*0.713*	*0.616*	*0.798*	*0.359*	*1.261*	*0.984*	*0.826*	*0.620*
	Outward	*1.574*	*0.717*	*0.195*	*0.000*	*2.304*	*1.071*	*0.316*	*0.000*
Reflexive density		*0.904*	*0.320*	*0.002*	*0.000*	*1.000*	*0.461*	*0.000*	*0.000*

B. The typological analysis of technological role and position

According to Figure 4-1, the reflexivity of the A block exhibits a consistently heavy density (Embodies = 0.904, Disembodied = 1). Meanwhile, the blocks of both technologies show significantly less reflexive density. This result indicates that the A block maintains internal reinforcement in terms of technology. Thus, the A block exhibits "social closure". The countries in the block mutually generate common interest, and this group demonstrates behavior that could be referred to as "the rich get richer". More specifically, the characteristic of internal reinforcement is more significant in a disembodied network form of the network than it is in an embodied network. From an inter-block perspective, in terms of inward density, this block demonstrates primary position [21]. The outer relationship or outward densities are notably high. For example, from A block to B and C blocks, the outward density remains high. However, the B block is relatively higher than the C block. This result indicates that the A block is cooperating more with the B block more than the C block is. On the other hand, in outward density terms, the A block demonstrates a generator role [37]. More specifically, the A block has a high level of density with the B, C, and D blocks. This result indicates that the A block provides a high degree of technology knowledge to the other blocks. However, the A block provides different information; in terms of disembodied technology, a source block acts as more of a typical technology provider than it does in an embodied form. Restated, disembodied technology diffusion tends to be more centralized than embodied diffusion. From a block reciprocity perspective, in Figure 4-1 the A and B blocks demonstrate high reciprocity. The inward and outward density from the B block is quite equal. However, the reciprocity between the A and C blocks is not; the outward density from the A block to the C block is higher than what the A block receives from the C block. Furthermore, there is no reciprocity between the A and D blocks. This result shows that C and D are consumers of the A block. Consequently, the A block acts as a technological generator, occupying a core position and maintaining a high reflexive density. The countries in this block mutually generate their common interest, and the members of this group enrich one another. In addition, the outward densities are notably high. Thus, A block acts as a generator [37].

An analysis of the B block position shows that this block has a moderate reflexive density in both forms. The result of Table 4-1 and Table 4-2 indicates that the embodied technology of B block ranges in density from 0.391 to 0.234, while disembodied technology is from 0.557 to 0.329. However, when compared with the A block, the B block is relatively lower. This result implies that the B block has less social closure. In the other words, countries in this block are less interactive or more passive in seeking mutual benefit. Therefore, this block is somewhat moderate in terms of reflexive density. Moreover, the reflexive density is significant lower in both technology networks than the A block. The data indicates that countries in the B block are positively interacting with countries in the A block rather than interacting with countries in the same position. Meanwhile, the B block also maintains outward ties to the C block in both technology networks. Despite the relatively low outward density between B and C blocks, the inter-block patterns are consistent with Burt's [21] broker position and Galaskiewicz and Krohn's [37] proposed role of transmitters. However, this distinctive feature may also imply that the B block is vertically integrated with the A block and that it can subcontract with the C block. On the other hand, the B and A blocks possess equity reciprocity, but the B and C blocks do not. The B block in both networks acts as a technology provider. Therefore, from an inter-block perspective, the B block is not only a major partner of the A block, but also acts as a minor technology provider for the C block. Therefore, the B block is in a "technological coordinator" position, with moderate reflexive density, high reciprocity with generators and low reciprocity with others. Due to this triad structure, coordinators can act as transmitters [37] or as brokers [21] to acquire profit.

The distinctive feature of the C block is rare reflexive ties. In Table 4-1 and Table 4-2, merely on term appears it (in 1999~2000). This result shows that countries in this block seldom interact with each other. In terms of inter-block density, the C block simultaneously interacts with the A and B blocks. According to Table 4-1 and Table 4-2, the C block with possesses moderate inward density and low outward density with the A block. Meanwhile, the C and B blocks have low inward density and rare outward density. This result indicates that the C block is able to export based on its low reciprocity with the A and B blocks. However, reciprocity between the C and A blocks is clearly greater than between the C and B blocks do. This result implies that the A block is a major company of the C block. From a diffusion pattern perspective, the C block demonstrates a "hanger-on" pattern. White, Boorman and Breiger [27] define a hanger-on relationship as a kind of follower. Therefore, the C block is consistent with Burt's sycophant typology rather than Galaskiewicz and Krohn's consumer typology. Furthermore, the relativity high reciprocity between the C and A blocks imply that late-developing countries select the most advanced countries as their major interactive partners, rather than countries whose technological capacity is similar to their own. As a result, the C block has a "technological follower" position with rare reflexivity; most interactions consist of acquiring technology rather than exporting. A major partner acts as a generator while a minor partner acts as a coordinator, creating a double hanger-on pattern [27] for followers. Burt [21] defines this characteristic as a sycophant typology.

Finally, the distinctive feature of the D block is that it is neither internally reflexive nor does it reciprocate with other blocks. It thus maintains similarities to the isolate typology in Galaskiewicz and Krohn's framework. However, because this block has no reflexive density, it is not consistent with Burt's isolate typology. Block D only interacts with block A, and their relations merely consist of inward density; the D block therefore exhibits Galaskiewicz and Krohn's consumer typology rather than Burt's sycophant typology. Accordingly, the D block acts as a typical technology consumer or absorber. Despite the fact that the D block acts as a consumer in both diffusion networks, there is a difference in the different forms of technology it consumes. Referring to Table 4-1 and Table 4-2, the inter-block density between the A and D blocks in a disembodied form (disembodied = 0.4~0.889) is higher than it is in an embodied form (embodied = 0.446~0.557). This result shows that the D block strongly utilizes disembodied technology for science and technology development. Thus, the D block maintains a position of "***technological absorber***"; it is neither internally reflexive nor does it provide reciprocity for other blocks. This position only interacts with generators and acts as a consumer [37].

Based on the information outlined above, this work proposes four typology blocks labeled as follows: technological generator, technological coordinator, technological follower, and technological absorber. Figure 4-2 shows a simplified graph of technological embeddedness typologies.

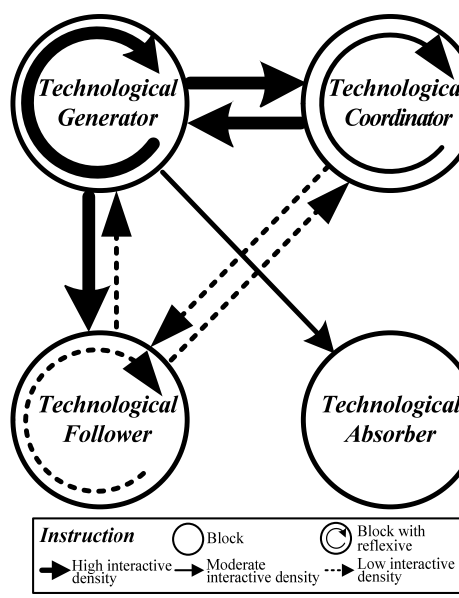

Figure 4-2: Roles and positional relationships of international technology diffusion

C. Technological embeddedness and development

Several findings remain insufficient to reveal the distinctive features of global technological embeddedness. This section attempts to discuss the results of the differences between embodied and disembodied diffusion, and the technological development in a radial-like dissemination environment [62]. It then proposes relevant implications in terms of technological development via network embeddedness. Table 4-3 shows sample countries in a technological embeddedness structure.

In terms of technological development, a typical position in Table 4-3 is that of a technological generator. This may be explained by the individual countries' political and economic ties with the other the sample countries. As shown in Table 4-3, the top seven countries (US, Canada, Germany, France, UK, Japan, and South Korea) are from the Triad regions of the global economy. Due to their advanced development in both economic and technological spheres, they have been able to achieve high outward density. Next, the dual-position countries of Australia, China, Hong Kong, the Netherlands, Singapore, and Taiwan can be split into Eastern and Western nations for this investigation. China, Hong Kong, Singapore, and Taiwan have developed aggressive exportation patterns following the examples set by the top seven nations. Australia and the Netherlands have their geographic and cultural European and historical connections which facilitate trade. It is interesting to note that China, Hong Kong, Singapore, and Taiwan were able to act as technological generators to Canada and five other European nations in technological coordinator positions for embodied technology diffusion; however, they are categorized as technological coordinators for disembodied technology. Consequently, these findings suggest that newly industrialized countries in East Asia reached technological generator positions in the international diffusion network with embodied technology earlier than with disembodied technology. Possible explanations for this could be that their economies are strongly export-oriented, and their economic growth relies significantly on international trade. For several decades, these three countries have received a large amount of FDI (Foreign Direct Investment), and have been the primary off-shore production locations for many multinational corporations; eventually these countries were transformed into manufacturing outsourcing centers. The influence of these foreign multinational corporations may have contributed to the swift advancement of their technological development, allowing them to achieve technological generator positions. In fact, many local firms from China and Taiwan have become ODM (Original Design Manufacturing) suppliers of foreign multinational corporations in their global supply chains. Furthermore, the acquisition of disembodied technology depends upon a country's absorptive capabilities [63], which makes it more difficult than the acquisition of embodied technology. Firstly, a leading position in the technological field raises the probability of patent citations in that field. Secondly, if a country has more patents in a variety of technological fields, there will be a higher frequency of citations due to the range of patents covered. This explains the top positioning of the US, Japan, South Korea, Germany, the UK, and France in the disembodied diffusion network while China and Taiwan have dropped to technological coordinator positions. Thus, this finding implies that a country's technological capability can more easily be enhanced through imported embodied technology than through disembodied technology.

TABLE 4-3: DENSITY BLOCKS OF A DISEMBODIED TECHNOLOGY NETWORK

1997 ~ 2008		Disembodied Technology			
		Technological Generator	***Technological Coordinator***	***Technological Follower***	***Technological Absorber***
Embodied Technology	***Technological Generator***	Canada, France, Germany, Japan, Korea South, United Kingdom, United States	Australia China Hong Kong Netherlands Singapore Taiwan		
	Technological Coordinator	Switzerland	Austria Belgium Brazil Denmark Finland Italy Norway Spain Sweden	Argentina India Mexico Poland Russia Turkey	Portugal
	Technological Follower			Hungary Ireland Malaysia South Africa	Greece Thailand
	Technological Absorber			New Zealand	Chile Colombia Iceland Indonesia Philippines

In terms of global technological embeddedness, the core-periphery structure and radial-like dissemination pattern [62] exhibits a rapid diffusion pattern. Global outsourcing, global supply chains, and international R&D have made international technology diffusion more global [64]. The core-periphery structure not only implies an increase in directly accessible diffusion routes, but also reveals the existence of polycentric dissemination. Flexibility, instantaneous mobility, and change create a time-space compression of physical and human processes and experiences. The notion of a small-world network [65] has become apparent.

However, new institutionalism [66, 67] maintains that an isomorphic mechanism, interpreting conformity to cognitive institutions, confers legitimacy and social fitness. Therefore, institutional environments affect supply chain management as well as manufacturing technology. Consequently, technological knowledge may diffuse along with international cooperation. However, technological isomorphism may then reduce heterogeneous technological capability and evoke homogeneous competition among technological generators and coordinators. Therefore, maintaining technological differentiation and innovation remains an important issue when a country gradually embeds itself in a cooperative network system.

V. CONCLUSIONS AND REMARKS

This study examines the network structure of international technology diffusion in terms of embodied and disembodied diffusion networks. It defines the structural configuration of countries within these two networks by measuring the interactive density of network embeddedness. Blockmodeling is used to position each country within four distinct blocks and also to distinguish aggregate relationships between the blocks. Thus, it demonstrates the applicability of network analysis in illustrating blocks of network roles of technological generator, technological coordinator, technological follower, and technological absorber. It also reveals the relationships that exist between embodied and disembodied diffusion networks. The following paragraphs summarize the empirical findings of this study.

Based on the blockmodeling, four blocks have been identified in both networks and have revealed global technological embeddedness as a global interactive graph with network roles. A technological generator has strong interactive density with others and possesses high values of inward and outward density. A technological coordinator also demonstrates high values of inward and outward density but less than the technological generator in both networks. A technological follower has begun to develop exporting technological knowledge capabilities to other countries based on the fact that outward density is much lower than inward density. A technological absorber features a zero value of outward density, and therefore can only absorb technological knowledge from advanced countries and lacking knowledge for reciprocal exportation. On the basis of reduced graphs of both networks, the technological generator acts as the main technology provider to the other network players. The technological coordinator primarily acquires technological knowledge from the technological generator and exports knowledge back to the technological generator and forward to the technological follower. The technological follower mainly depends on the absorption of technological knowledge from advanced network players and also exports its limited knowledge to the technological generator. The technological absorber merely acquires technological knowledge from the technological generator.

In terms of global technological embeddedness, both embodied and disembodied technology diffusion networks demonstrate significant core-periphery features. Both networks show significant global stratification patterns in the capability of a country's international technology exportation. Therefore, network mobility is another central issue. On one hand, newly industrialized countries in East Asia have reached technological generator positions in the international diffusion network with embodied technology earlier than with disembodied technology. This finding implies that a country's technological capability can be enhanced through imported embodied technology more easily than through disembodied technology. On the other hand, technological isomorphism may evoke homogeneous competition. Maintaining technological differentiation and innovation remains an important issue when a country gradually embeds itself in a network system.

Limitations of this study that may provide directions for future research, and are as follows: international technology diffusion involves several different channels. Countries do not merely conduct a single type of international activity associated with technology transfer; but rather perform several such activities, such as foreign direct investment, licensing, joint ventures, movement of personnel, and so on. Therefore, consideration of several technological channels for future study is needed. Additionally, international R&D and global supply chains may dynamically evoke technology diffusion, and this global activity can be an issue for further study.

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APPENDIX A: COUNTRIES OF INTERNATIONAL TECHNOLOGY DIFFUSION AND REGE BLOCKMODELING POSITION

Country	Years						
	1997~1998	1999~2000	2001~2002	2003~2004	2005~2006	2007~2008	**Over All**
Argentina	2,3	2,3	4,3	4,3	3,3	3,3	**2,3**
Australia	1,2	1,2	1,1	1,2	1,2	1,2	**1,2**
Austria	2,2	2,2	2,2	2,2	2,2	2,2	**2,2**
Belgium	2,2	2,2	2,2	2,2	2,2	2,2	**2,2**
Brazil	2,2	2,2	1,2	1,2	2,2	2,2	**2,2**
Canada	1,1	1,1	1,1	1,1	1,1	1,1	**1,1**
Chile	3,4	4,4	4,4	4,4	4,4	4,4	**4,4**
China	1,2	1,2	1,2	1,2	1,2	1,2	**1,2**
Colombia	4,4	4,4	4,4	4,4	4,4	4,4	**4,4**
Denmark	2,2	2,2	2,2	2,2	2,2	2,2	**2,2**
Finland	2,2	2,2	2,2	2,2	2,2	2,2	**2,2**
France	1,1	1,1	1,1	1,1	1,1	1,1	**1,1**
Germany	1,1	1,1	1,1	1,1	1,1	1,1	**1,1**
Greece	2,4	3,3	4,3	3,4	3,3	3,3	**3,4**
Hong Kong	2,2	3,2	1,2	1,2	1,2	1,2	**1,2**
Hungary	3,3	3,3	3,4	3,3	3,3	3,3	**3,3**
Iceland	4,4	4,4	4,4	4,4	4,3	4,3	**4,4**
India	2,3	3,3	3,3	2,2	2,2	2,2	**2,3**
Indonesia	4,4	4,4	4,4	4,4	4,4	4,4	**4,4**
Ireland	3,3	3,3	3,3	3,2	3,2	3,2	**3,3**
Italy	2,2	2,1	2,1	2,2	2,2	2,2	**2,2**
Japan	1,1	1,1	1,1	1,1	1,1	1,1	**1,1**
Korea, South	1,1	1,1	1,1	1,2	1,2	1,2	**1,1**
Malaysia	3,4	3,4	3,3	3,3	3,3	3,3	**3,3**
Mexico	2,3	2,3	1,3	2,3	2,3	2,3	**2,3**
Netherlands	1,2	1,2	1,1	1,2	1,2	1,2	**1,2**
New Zealand	4,3	4,3	4,3	4,2	4,2	4,3	**4,3**
Norway	2,2	2,2	2,2	2,2	2,2	2,2	**2,2**
Philippines	4,4	4,4	4,4	4,4	4,4	4,4	**4,4**
Poland	2,3	2,3	2,4	2,4	2,3	2,3	**2,3**
Portugal	2,4	2,3	2,4	2,4	2,4	2,3	**2,4**
Russia	2,3	3,3	2,3	2,3	2,3	2,2	**2,3**
Singapore	1,2	1,2	1,2	1,2	1,2	1,2	**1,2**
South Africa	3,3	3,3	3,3	3,3	3,3	3,3	**3,3**
Spain	2,2	2,2	2,2	2,2	2,2	2,2	**2,2**
Sweden	2,2	2,1	2,1	2,1	2,2	2,2	**2,2**
Switzerland	2,1	2,1	2,1	2,2	2,2	2,2	**2,1**
Taiwan	1,2	1,2	1,2	1,2	1,2	1,2	**1,2**
Thailand	3,4	3,4	3,4	3,4	3,4	3,4	**3,4**
Turkey	2,4	2,3	2,4	2,3	2,3	2,3	**2,3**
United Kingdom	1,1	1,1	1,1	1,1	1,1	1,1	**1,1**
United States	1,1	1,1	1,1	1,1	1,1	1,1	**1,1**

Note: Block code table

		Disembodied			
		1. *A*	2. *B*	3. *C*	4. *D*
Embodied	1. *A*	1,1	1,2	1,3	1,4
	2. *B*	2,1	2,2	2,3	2,4
	3. *C*	3,1	3,2	3,3	3,4
	4. *D*	4,1	4,2	4,3	4,4

A represent as Technological Generator.
B represent as Technological Coordinator.
C represent as Technological Follower.
D represent as Technological Absorber.